TOWARDS AN OPTIMAL FINANCIAL INVESTMENT DECISION IN BUILD-OPERATE-TRANSFER PROJECTS USING GENETIC ALGORITHMS

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ABSTRACT

Investments into large, green-field infrastructure projects under build-operate-transfer arrangements are challenging, and present complex issues for potential project promoters. To demonstrate, during the tendering stage, the two main concerns for project promoters are ensuring a certain level of profit margin, and making the financial proposal as attractive as possible to the client. Hence, from the project promoter's point of view, a state of optimality exists between selections of the right combination of key financial factors with appropriate values. Prior research in this area is limited, and has only partially addressed this optimization issue in a fragmented fashion.

This paper provides a novel approach by integrating the leading financial elements pertaining to capital budgeting and project financing aspects, which in turn ensures optimum financial viability to promoters. Optimality equations and constraints, based on discounted cash flow analysis are developed, and the non-linear behavior of the objective function is accounted for. Finally, a genetic algorithms-based financial optimization model is developed to reach the near-optimal solution for maximizing the winning potential of the concession agreement under a reasonable profit margin from the equity holder's perspective**.** The proposed model is demonstrated through a numerical example, which will help improve the financial decision-making processes in an efficient and effective way.

KEY WORDS

construction industry, decision making, evolutionary computation, financial management, optimization.

INTRODUCTION

Governments often have to invite private entities in order to promote green-field public infrastructure projects due to several reasons, including funding constraints. The most common form of contractual arrangement that many governments adopt for project delivery systems is build-operate-transfer (BOT), or its variants. However, due to off-balance-sheet

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financing arrangement, participation into privately-financed public infrastructure projects becomes a complex and challenging issue to prospective project promoters, in particular, when the projects are selected through competitive tendering procedures. To be eligible, to become pre-qualified, and thereafter to design a competitive tender proposal, promoters have to spend a substantial amount of financial and other resources. At the tendering stage, therefore, the prospective project promoters' desire to win the concession agreement is due to three main reasons: (1) possible opportunity of realizing potential profitable income; (2) large initial expenditure already spent; and (3) ongoing reputation.

Profitability, as well as a winning prospect of the concession, plays a pivotal role in designing the tender proposal, particularly the financial proposal. As the main concern of project promoters is to earn a reasonable amount of return from their investment, appropriate values of initial price of the product and length of the concession period become the main decision variables that should be extensively reviewed in investment appraisal, along with other financial parameters. Regarding winning potential, project promoters should cater for government interests, so the financial proposal becomes attractive to the government. The government is mainly interested in two important financial aspects of a BOT facility: (1) during the concession period, the project should not exert excessive financial burden to its public, including higher prices; and (2) after handover, the government should not face at least any financial loss from running the project till the end of its economic life, which is related to the concession period (Shen et al. 2002). Usually, the government will prefer the financial package that combines a low price with a low concession period. In contrast, overemphasizing to comply with government requirements may substantially trim down the promoter's profitability. Hence, conflicting interests prevail between the two parties in setting out an acceptable combination for initial product price and concession length.

Another central issue the government is constantly looking for is the ability of project promoters to raise the required amount of finance. During the negotiation stages, project promoters are requested (and in some cases dictated) by the government to inject a certain amount of equity to the stipulated initial investment so project promoters' financial commitment can be accomplished (Tiong 1995), as well as ensuring lenders are feeling encouraged providing financial guarantees in favor of project promoters. Conversely, equity holders always want to keep their equity as low as possible (Zhang 2005) because of its lower payment priority and higher risk involvements. Hence, the identification of a suitable equity ratio is becoming a decisive financial factor concerning project financing that also involves different interests to different parties. Thus, from the capital budgeting perspective, price and concession length, and from the project financing perspective, equity ratio are the critical financial cum contractual elements that should be carefully designed in satisfying the mutual interests of both project sponsors and project promoters.

PREVIOUS STUDIES

The paramount importance of the aforesaid factors has been recognized by many researchers in the past, but the factors were addressed individually, or to some extent collectively, as decision variables in evaluating financial return to project promoters. Ngee et al. (1997) introduced a prediction model by using a multiple linear regression technique for determining financial performance measures of promoters from a given combination of tariff and concession length. The study was limited in the sense that their model was problem-dependent, and the predicted variable was derived by keeping all other financial parameters constant. More recently, Lianyu and Tiong (2005) presented a simulation-based minimum feasible tariff model for a BOT water supply project that explains the possible lowest allowable price of products at risk under various risk allocation strategies. Bakatjan et al. (2003) addressed the issue of project financing by employing a linear programming technique for obtaining the optimal capital structure of a BOT power project. More recently, Zhang (2005) refined the concept of optimal capital structure by incorporating equity at project risks, and devised a methodology based on iteration and simulation. Using a simulation technique, effects of concession structure on a BOT project's viability was demonstrated in the work of Ye and Tiong (2003), while Shen et al. (2002), and Shen and Wu (2005), developed mathematical models and used simulations to illustrate how the length of the concession period affects financial interests of both promoters and sponsor alike.

Two significant observations have been drawn from the literature review. Firstly, none of the above studies has concentrated to aggregate the effect of capital budgeting and project financing issues in analyzing the financial viability of BOT projects, thereby not exploring the combined effect of relevant financial factors as decision variables. This is required for simultaneous investigation of profitability and bid-winning probability from the project promoter's point of view. Secondly, most of the previous studies used simulation to derive the results. Simulation as a stand-alone technique does not meet the optimization requirement because the simulation replicates real-world situations through a trial-and-error process, which is more sensitive to input data. Furthermore, as the output of simulations is merely a series of scenario analyses, the optimal satisfaction of the objective function cannot be directly attainable from the result. This view is also shared by Render et al. (2006), who state: "simulation does not generate optimal solutions to problems" and "could produce different solutions in successive runs".

The motivation of this study thus arises from the realization of these clear caveats concerning the need to incorporate both capital budgeting and project financing issues, as well as for devising an improved methodology for analyzing the financial viability of BOT projects from the project promoter's stance. The primary focus of this paper is, therefore, to develop a financial optimization model that will examine how the concessionaire could best enhance their bid-winning likelihood during the tendering stage by determining the optimal combination of decisive financial factors under a certain profit margin level that also satisfies all necessary financial constraints. The model will enhance efficiency in providing quicker decisions to design a competitive financial proposal and process effectiveness in yielding more transparency to reveal financial targets.

FINANCIAL MODEL

The well-known discounted cash flow techniques are used to derive the financial model. Total project cost is estimated based on current cost estimate, which consist of three components: (1) year wise distribution of the initial, stipulated investment estimated at the beginning of a project; (2) cost escalation due to inflation; and (3) capitalized interest to debt, drawn during the construction period (Ranasinghe 1996). The total project cost and its components are expressed as:

$$C_{TPC} = C_{BC} + C_{INF} + C_{INT} \tag{1}$$

$$C_{BC} = \sum_{i=1}^{m} BC_i = \sum_{i=1}^{m} \delta_i \times ISC \tag{2}$$

$$C_{INF} = \sum_{i=1}^{m} C_{INF}^{i} = \sum_{i=1}^{m} \left[BC_i \left\{ \left(\prod_{k=1}^{i} (1+\theta_k) \right) - 1 \right\} \right] \tag{3}$$

$$C_{INT} = \sum_{i=1}^{m} C_{INT}^{i} = \sum_{i=1}^{m} (1-e) \times \sum_{k=1}^{i} \left[BC_k \times \{(1+r) - 1\} \right] \tag{4}$$

where C_{TPC} = total project cost; C_{BC} = base cost; C_{INF} = total cost escalation due to inflation; C_{INT} = total financing cost; BC_i = initial cost in the i^{th} year; δ_i = percentage of initial stipulated cost in the i^{th} year; ISC=initial stipulated cost, which is the sum of construction cost and other cost; m=length of construction period (in years); i = specific year of construction period so that $i \in [1,m]$; C_{INF}^{i} = cost escalation at the i^{th} year; θ_k = cost inflation rate at the k^{th} year; C_{INT}^{i} = interest on debt drawn at each year of grace period; r = interest rate of debt; e= equity ratio.

The accumulated debt at the end of the construction period is considered to be repaid in annual equal installments. Annual equal debt installments are calculated by using the capital recovery factor and annual interest of debt, according to White (1998) as follows:

$$ADI_j = (1-e) \times ISC \times \left[\frac{r(1+r)^N}{(1+r)^N - 1} \right] \tag{5}$$

$$INT_j = ADI_j \times \left[1 - \frac{1}{(1+r)^{(n-j+1)}} \right] \tag{6}$$

where ADI_j =annual equal debt instalments in the j^{th} year; N = loan repayment period (in years); j = year of operation so that $j \in [1,n]$; n = operation period (in years); INT_j = annual interest of debt in the j^{th} year.

Gross revenue is a function of market demand and pricing, which is determined as:

$$REV = \sum_{j=1}^{n} REV_j = \sum_{j=1}^{n} \left[\left\{ P_o \prod_{k=1}^{j} (1 + g_P^j) \right\} \times \left\{ Q_o \prod_{k=1}^{j} (1 + g_Q^j) \right\} \right] \tag{7}$$

where P_o = base price at start of operation period; Q_o = base demand at start of operation period; g_P^j = annual growth rate of price; g_Q^j = annual growth rate of demand.

Annual profit before interests and tax, and annual net cash flow available to project promoters is defined (Bakatjan et al. 2003) as follows:

$$PBIT_j = REV_j - OMC_j - DEP_j \tag{8}$$

$$NCF_j = REV_j - OMC_j + DEP_j - ADI_j \tag{9}$$

where $OMC_j = \lambda \times ISC$ = annual operation and maintenance cost; λ = percentage of initial stipulated cost; $DEP_j = \frac{C_{TPC}}{n}$ = annual depreciation rate considering total project cost will be depreciated within the operation period by using the straight line depreciation method.

Amount of profit to project promoters by undertaking the concession project is expressed in net present value (NPV). Combining Eq.(1) through Eq.(9), the equity NPV is defined as:

$$E_{NPV} = -\sum_{i=1}^{m} \left[\frac{e \times BC_i + C_{INT} + C_{INF}}{(1 + wacc)^i} \right] + \sum_{j=1}^{n} \left[\frac{NCF_j}{(1 + d)^{(m+j)}} \right] \tag{10}$$

where E_{NPV} =Equity NPV; wacc = weighted average cost of capital and is further defined as: wacc= d .e + d. (1-e) .(1-t); d=discount rate; t=tax rate.

It is noteworthy to mention that subject to satisfying financial constraints, the equity NPV as shown in Eq. (10) can be achieved by many combinations of base price and concession length for a desired level of profit, which is defined here as an equity benefit cost ratio. Project promoters should select the equity NPV that would simultaneously yield lower price and a lower concession length in terms of operation period as much as possible to a corresponding desired profit level. In other words, maximization of a winning chance for a bid could be obtained by considering the maximization of profit per operation period per offer price. At the same time, concessionaires should also consider their financial strength for funding the project, thereby selecting a comfortable level for equity contribution to the initial stipulated investment. Considering the financial strength of the concessionaire as well as the winning probability, a financial index is developed to measure the bid-winning potential of the project promoters as:

$$\mathrm{BWI} = \left[\frac{\mathrm{E_{NPV}} \times \mathrm{e_{CL}}}{\mathrm{n} \times \mathrm{P_o}}\right] \qquad (11)$$

where BWI = the bid winning index; e_{CL} = comfort level to corresponding equity injection.

Self-financing arrangements and government return are catered for by constructing financial constraints. Debt service coverage ratio (DSCR) in each year of the loan repayment period must not be less than 1.1 (Zhang 2005) indicating that NCF, during the loan repayment period, is positive.

$$\mathrm{DSCR_j} = \left[\frac{\mathrm{PBIT_j} - \mathrm{TAX_j} + \mathrm{DEP_j}}{\mathrm{ADI_j}}\right] \geq 1.1 \qquad (12)$$

Revenue after the loan repayment period until the end of the concession period must not be less than the operation and maintenance cost and tax, if any (Malini 1999).

$$\left[\mathrm{R}EV_{\mathrm{j}} - \mathrm{O}MC_{\mathrm{j}} - \mathrm{TAX_j}\right]_N^n \geq 0 \qquad (13)$$

Government return from running the project after the concession period till the end of the economic life of the project must be positive (Shen and Wu 2005).

$$\mathrm{G_{NPV}} = \sum_{\mathrm{l}=1}^{\mathrm{o}} \left[\frac{\mathrm{REV_l} - \mathrm{OMC_l}}{(1+\mathrm{d})^{(\mathrm{m}+\mathrm{n}+\mathrm{l})}}\right] \geq 0 \qquad (14)$$

GENETIC ALGORITHMS

Genetic algorithms (GAs) are a probabilistic, heuristic search technique inspired by biological evolution in nature (Goldberg 1989). Computationally, GAs involve the algorithms that direct a system under consideration to follow Darwin's principle of 'survival of the fittest' in order to derive the optimal solution from the system. The first step of GA operation is to characterize the objective function through a suitable coding of the chromosomes. The chromosomes in this study consist of a base price of the product, concession length and equity ratio. Since the problem contains chromosomes comprising both integer and floating point decision variables, the real-valued coding system is adopted. Advantages of real-valued coding over binary coding, including its processing efficiency, have been well documented in Wright (1991). GAs begin their operation to work on an initial, randomly-generated population and thereafter, undertake successive generations of the populations. Basic GA operators are described succinctly in the following subsections.

Selection guides the chromosomes to be qualified as parents for the next generation. The roulette wheel selection method based on rank weighting is used to construct the mating pool. In this method, chromosomes are first sorted according to their actual value-based fitness; each chromosome is then assigned a contiguous segment of the roulette wheel according to its rank value. This method is used because it provides uniform scaling across chromosomes within the population; for more details reader(s) can consult Wang et al. (1997).

The crossover operation creates new chromosome(s) from the two parent chromosomes by intermingling parts of the information from each. Considering the real-valued representation, the arithmetic extrapolation one-point cut crossover method is opted for. This method is used due to its capability, as pointed out by Haupt and Haupt (2004) "to closely mimic the advantages of the binary GA mating scheme". The arithmetic extrapolation adopts the following form of linear combination:

$$\begin{cases} g_1^o = g_1^p - \beta\left[g_1^p - g_2^p\right] \\ g_2^o = g_2^p + \beta\left[g_1^p - g_2^p\right] \end{cases} \tag{15}$$

where g_1^o and g_2^o are the new values of the selected genes for the two offspring; g_1^p and g_2^p are randomly selected genes from two parent chromosomes; and β is a random number spanning between [0, 1]. The number of chromosomes to be crossed over per generation is selected by the user-defined input, called the probability of crossover, P_c.

Mutation alters the value of selected gene(s) of a chromosome within a specified bound. Uniform random mutation is chosen, which selects and alters both the gene and its real value, randomly. The probability of mutation, P_m defines the number of genes to be mutated within the population. In order to improve GA performance, the elitism principle is also applied; only the top-performing chromosome is not mutated, and is retained for future generations.

GAs cannot be directly applicable to constrained optimization problems (Yeniay 2004). Penalty functions are the most popular strategy for handling constrained optimization problems in GAs (Coello Coello 2001). In this paper, the penalty function method developed by Kuri-Morales and Quezda (1998) has been used, and is defined as:

$$F(x) = \left[K - \sum_{s=1}^{L} \frac{K}{M}\right] \quad \text{for } L \neq M \tag{16}$$

where F(x) = penalty function; K = a large constant; L = number of non-violated constraints; and M = total number of constraints. The advantage to this method is its flexibility of using information about the number of violated constraints, which is the requirement for this paper.

FINANCIAL OPTIMIZATION MODEL

The proposed algorithm is designed to maximize the chance of winning a concession agreement as stated in Eq. (11), which is therefore, considered as the objective function. The vector of decision variables consists of base price, concession length and equity ratio. The financial constraints are shown in Eqs. (12) to (14). Note that in cases of violation of the constraints, Eq. (16) will replace the objective function, and the infeasible solutions will be graded much more poorly than the feasible ones according to the degree of violation of the constraints. The algorithm is shown in Figure 1.

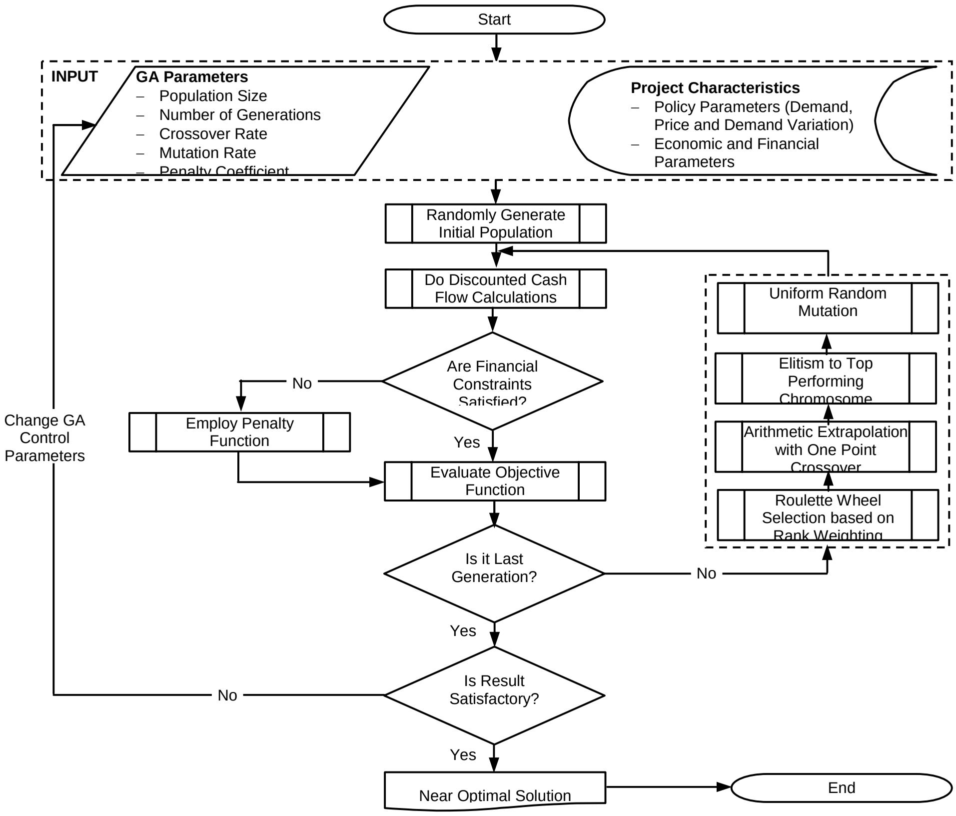

Figure 1: Flow Chart of BOT Financial Optimization Model using GA

NUMERICAL EXAMPLE

The capability of the financial optimization model is illustrated by utilizing the data published in Bakatjan et al. (2003), which has been selected because of its comprehensiveness. The economic and financial parameters are depicted in Table 1.

Table 1: Economic and Financial Parameters (Source: Bakatjan et al. 2003)

Project Characteristics	Deterministic Values	Price Variations	
		Year of Operation	Year wise Price as % of Base Price
Economic Life	20 years	Year 1	100%
Construction Period	4 years	Year 2	95%
Loan Repayment Period	10 years	Year 3	90%
Initial cost (thousands USD)	132565	Year 4	86%
Annual O & M Cost	0.60% of Initial Cost	Year 5	81%
Inflation Rate	4.1%	Year 6	77%
Loan Interest Rate	10%	Year 7	74%
Discount Rate	12%	Year 8	70%
Tax Rate	11%	Year 9	66%
Demand (GW.h)	405.8	Year 10	63%
Demand Variation	Constant	Year 11-20	25%

The size of the population should vary between 30 and 500 (Goldberg 1989). The population size of this model is set to 200. After successive attempts, the combination of crossover rate of 0.6 and a mutation rate of 0.1 seems to produce the best result in terms of model convergence that is, producing acceptable results under stable condition. A large penalty coefficient (10^7) is adopted for using the penalty function. It was observed that 1000 generations are good enough for arriving at a stable condition, and producing near optimal solutions. The algorithm is coded in the MATLAB software package.

Results obtained from the model are shown in Table 2 where, for a particular level of profitability, decision-makers may choose near optimal decision vectors coupled with maximizing the probability of winning a concession agreement.

Table 2: Optimal Decision Variables

Profitability Level	**Objective Function**	**Optimal Decision Vector()***		
	Bid Winning Index	**Concession Period (Year)[a]**	**Equity Ratio**	**Unit Price (cents/kW.h)**
1.2	4175	12	0.22	10.38
1.5	9437	12	0.24	11.86
1.8	13312	12	0.23	13.23
2.0	16339	12	0.29	14.58
2.5	20758	12	0.28	17.05
3.0	24054	12	0.28	19.53

a: excluding construction period

It is worth mentioning that Bakatjan et al. (2003) have attempted to determine the optimal equity level given the fact that all relevant financial factors including the base price, and the length of the concession are known in advance. Using a pre-assigned value of base electricity tariff as 9.04 cents/kW.h, and a concession length of 24 years, they found the optimal mix of debt-to-equity ratio as 0.6831:0.3169, which yields the profit margin of 14.74 %; measured in terms of internal rate of return (IRR) from the equity holder's point of view.

In contrast, the advantage of the proposed model is that it does not require to pre-assume/estimate the value of the base price and concession length, rather it automatically and simultaneously determines a competitive and optimal set of the decision variables.

Although the contexts are different, only the first set of near optimal solutions obtained from the proposed model (refer to row 1, Table 2) is verified with the findings of Bakatjan et al. (2003) because of their similar level of profit margin. The equity level obtained from the model ranges from 22% to 29% of the stipulated initial investment cost, which is comparable to the equity value of 31.69% determined by Bakatjan et al. (2003). Furthermore, it could be observed that a higher profitability level demands a comparatively higher equity ratio because of its strength in reducing total project cost. The base electricity tariff for different profit-margins ranges from 10.38 cents/kW.h to 19.53 cents/kW.h.

However, considering the profitability level, expressed in terms of equity benefit cost ratio as 1.20, which is closer to the equity IRR of 14.74%, the near optimal value of equity level is found to be 22% and the base price required for maximizing the bid-winning probability is found as 10.38 cents/kW.h. The base electricity tariff is slightly higher in comparison to 9.04 cents/kW.h, because of the slightly higher profitability level as well as decreased period of concession length, particularly the project operation period.

The non-linear increasing trend of the bid-winning probability index under different profit levels is shown in Figure 2. The corresponding increase in base price is exemplified in Figure 3.

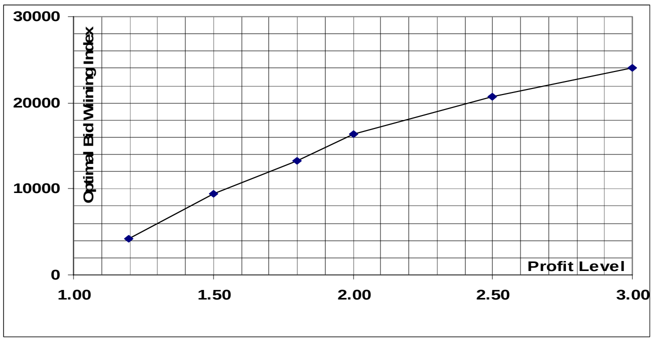

Figure 2: Optimal Design Graph for Concession Agreement Winning Index

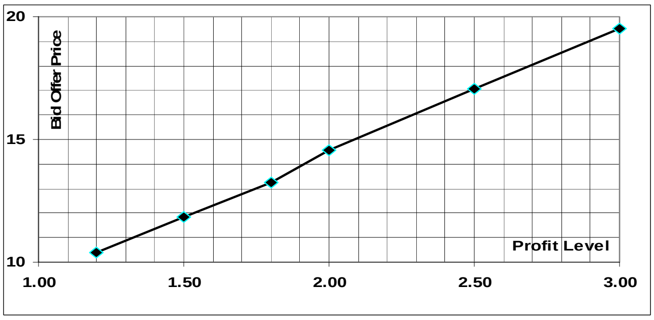

Figure 3: Optimal Base Price at Different Profit Levels

CONCLUSION

Simultaneous considerations of profitability as well as bid-winning prospects are vital to project promoters for evaluating the financial viability of BOT projects, particularly in order to make the financial proposal competitive. Previous work did not explicitly incorporate the issue of maximizing the winning potential of a concession agreement through integration of capital budgeting and project financing features.

In this paper, a new financial index is formulated to measure the bid-winning potential of the project promoters from a financial perspective. Based on the developed financial index, a deterministic, single-objective financial optimization model is proposed using genetic algorithms in order to find the optimal combination of key financial factors, namely: base price of product, length of concession period, and equity ratio that would maximize the chance of winning a concession. Future research is underway for incorporating the impact of risks on economic and financial variables into the proposed genetic algorithms-based financial optimization model.

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